# VISUAL REFERENCE STANDARDS FOR WELD SURFACE CONDITIONS AND USER'S GUIDE FOR WELD REPLICAS

SP7 PROJECT REPORT FUNDED BY MARITIME ADMINISTRATION OF THE U.S. DEPARTMENT OF COMMERCE AND THE U.S. DEPARTMENT OF THE NAVY IN COOPERATION WITH THE AMERICAN BUREAU OF SHIPPING, NEWPORT NEWS SHIPBUILDING, AND INGALLS SHIPBUILDING, INC.

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**PANEL CHAIRMAN's NOTE:**

The first phase of this project began in 1980. The plastic replicas and this guide is the culmination of much effort and many hours of work supplied by numerous individuals.

Panel members provided numerous steel assemblies to be considered for replication. Because of the large number of samples from which to select, a special Ad-Hoc Committee of panel members was appointed and these individuals performed a yeomans task of narrowing the field to the 32 samples used for modeling. The panel membership considered these final samples at a meeting and concurred with the Ad-Hoc Committee's selections.

The basic philosophy of the selection process was to develop three levels of magnitude for each imperfection type. Whenever possible, a published standard was used for comparison of the model's visual attributes and these are reported in the guide.

The objective of this project was not to establish standards for acceptance of visual quality for welds but rather, the samples are to be used as a tool for discussions and agreements between the producer and the customer. In this sense, a customer can be a Quality Assurance Department as well as the ultimate user of the welded product.

Each organization that possesses and utilizes these samples can define the use and function of the replicas to suit their own needs. The SP-7 panel has attempted to provide a service to the shipbuilding industry which can be multipurpose and of considerable value.

L. G. Kvidahl, Chairman
SPC Panel, SP-7

NSRP No. 0338
SEPTEMBER 1991

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

# VISUAL REFERENCE STANDARDS FOR WELD SURFACE CONDITIONS (PHASE III) AND USER's GUIDE FOR WELD REPLICAS

TASK 7-84-11

THIS PROJECT WAS PERFORMED FOR THE NATIONAL SHIPBUILDING RESEARCH PROGRAM BY THE AMERICAN BUREAU OF SHIPPING AS THE THIRD AND FINAL PHASE OF A THREE PHASE PROJECT ORIGINATED BY THE SP 7 PANEL OF THE SHIP PRODUCTION COMMITTEE OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS. FUNDING FOR THE WORK WAS PROVIDED UNDER MARITIME ADMINISTRATION CONTRACT DTMA 91-84-C-41028 WITH NEWPORT NEWS SHIPBUILDING (PHASE I AND II) AND WITH INGALLS SHIPBUILDING (PHASE III)

## FOREWORD

The purpose of this report is to present the third phase of a research and development program which was initiated by the members of the Ship Production Committee of The Society of Naval Architects and Marine Engineers. The cost was shared by U.S. Maritime Administration, the American Bureau of Shipping and Ingalls Shipbuilding. The aim of this project was directed to the production of three dimensional sample illustrations of weld surface conditions, applicable to visual weld inspection.

Phase I addressed the conditions of cluster porosity, scattered porosity, and undercut; Phase II addressed the conditions of weld surface roughness, irregular contour, and re-entrant angle. Phase III is addressed to the manufacture of the plastic weld replicas.

A special acknowledgment is made to the members of Welding Panel SP-7 of the SNAME Ship Production Committee who served as technical advisors in the preparation of inquiries and evaluation of subcontract proposals, and to Mr. L.G. Kvidahl, SP-7 Panel Chairman and to Mr. O.J. Davis, Ingalls Shipbuilding, SP-7 Program Manager.

The program was carried out by the American Bureau of Shipping; Mr. William Hanzalek was the Project Manager; Dr. D.Y. Ku, and Mr. R.F. Waite served as Project Engineers.

Appreciation is also expressed for the contribution of weld samples by the following companies:

* Avondale Shipyards, Inc.
* Bath Iron Works Corporation
* Bay Shipbuilding Corporation
* Bethlehem Steel Corporation
* FMC Corporation
* Fraser's Boiler Service
* General Dynamics Corporation
* Ingalls Shipbuilding Division
* Newport News Shipbuilding
* Pennsylvania Shipbuildikng
* Portsmouth Naval Shipyard
* Tacoma Boatbuilding Company
* Todd Pacific Shipyards Corporation

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## 1. ABSTRACT

In Phase I and Phase II of the project, weld samples were produced illustrating five types of weld surface conditions at three levels of severity in butt and fillet welds. The samples can be related to some existing descriptive acceptance standards used in the marine industry, and could form the basis for a guide for the evaluation of weld surface conditions which could be applicable to the various structural and pressure vessel requirements of the marine industry. The use of such illustrations, replicated as plastic models, could reduce the frequency of making physical measurements of weld surface conditions, and also reduce the subjective considerations in evaluating weld surfaces. The replicas cover the conditions of undercut, cluster porosity, scattered porosity, roughness, irregular contour and re-entrant angle. The primary task of Phase III is to manufacture the plastic replicas for distribution to the marine industry as reference standards for the evaluation of weld surface conditions.

## 2. INTRODUCTION

Visual inspection is the most extensive nondestructive method used for weld evaluation. Judgements, however, as to the acceptability of welds based on visual examination may be controversial in that existing codes and specifications lack sufficiently clear and objective criteria for certain weld surface conditions. Some codes define the acceptable level of some surface conditions quantitatively (e.g. size and number of pores, depth of undercut, etc...); others use general descriptive terms (e.g. "reasonably free from undercut and overlap"). Irregularities in weld surface conditions along the length of the weld or transverse to the weld are also difficult to define quantitatively; however, it is generally agreed that at some level, such irregularities should be considered indicative of a weld of unacceptable quality on the basis of a subjective judgement. When subjective judgement is involved, experts may not always agree on the acceptance of a given weld, even when evaluated against a descriptive standard. Consequently, there is an apparent need to reduce the subjective considerations involved and to augment descriptions in existing codes and specifications.

In the course of the deliberations of the SNAME SP-7 Welding Panel, it was agreed that a viable approach to meet this need would be the development of plastic replicas of welds with various gradations of different weld surface conditions and with supplementary descriptions.

This report represents the third phase of an overall program to develop three-dimensional sample illustrations of weld surface conditions for use as reference standards by shipyards, specifications writing bodies, technical societies and fabricators. Phase I of this project developed samples representing scattred porosity, cluster pososity, and undercut. In Phase II samples illustrating roughness, irregular contour, and re-entrant angle were developed. In Phase III the plastic replias were manufactured for the samples developed in the previous two phases for distribution to the marine industry as reference standards for the evaluation of weld surface conditions.

## 3. OBJECTIVE

The primary objective of Phase III was to manufacture selected samples from Phase I and Phase II, illustrating weld surface conditions with appropriate gradations of severity not amendable to quantitative written descriptions.

## 4. APPROACH

The initial approach in Phase I and Phase II was to produce samples illustrating the following surface conditions in butt and fillet welds: undercut, porosity, roughness and contour (including re-entrant angle, overlap, convexity and concavity). In the course of work, in Phase 1, it became evident that porosity should be expanded to two categories - scattered and clusters. Upon further consideration, in Phase II, it was determined that overlap, convexity and concavity should be eliminated from the program since they were adequately defined in codes and/or could be conveniently measured with standard gauges.

For roughness, irregular contour and re-entrant angle, they are defined as follows:

a) Roughness: Condition of surface irregularities along the longitudinal axis of the weld.

b) Irregular Contour: Condition of surface irregularities along the transverse axis of the weld.

c) Re-entrant angle: The angle between the plane of the parent metal surface and a plane tangential to the weld bead surface at the toe of the weld.

## 5. PROCEDURE

The SNAME SP-7 Welding Panel members were requested to submit samples, which in their individual judgement are representative criteria for the following:

1) The minimum quality level appropriate to critical applications - Severity Level A

2) The minimum quality level appropriate to general applications - Severity Level B

3) The minimum quality level appropriate to secondary applications - Severity Level C

Samples were first evaluated using AWS D1.1 criteria for undercut and porosity and then selected by the consensus of SNAME SP-7 Welding Panel.

This first selection of samples represented the minimum levels acceptable according to AWS D1.1. Additional samples were selected to represent one higher and one lower quality level.

The three levels, namely Level A, Level B and Level C, of undercut, scattered porosity, and cluster porosity reflected by the samples were measured and then defined as indicated in Table I. The selection of representative samples illustrating roughness and irregular contour was based on the consensus of the members of SNAME SP-7 Welding Panel. The selection of representative samples illustrating re-entrant angle was selected based on actual measurements revolving around 90 degrees. Each sample was machined to the following dimensions:

Butt Weld - 6" L x 2" W x 0.5" T
Fillet Weld - 6" L x 1.5" W x 2" H x 0.5" T

The six inch length was chosen because many codes address the allowable distribution of weld surface conditions in multiples of six inches of weld length.

Sample codes for plastic weld replicas are shown in Table II. Five sets of samples of butt and fillet welds have been produced; each set illustrates three levels of severity of surface condition for undercut, scattered porosity, cluster porosity, roughness and irregular contour and one butt and fillet weld illustrate re-entrant angles near 90 degrees.

## 6. DISCUSSION

The relationship between the specific conditions represented by the samples and the specific requirements in the codes is shown in Table IV for undercut and scattered porosity. As indicated therein, a code may have different requirements for fillet welds and for butt welds, and may not permit any level of a particular type of defect; with respect to the A,B, and C levels of illustrations proposed, an additional level "O" should be used to designate an absence of conditions. For example: AWS D1.1 requires that "butt welds transverse to the direction of computed tensile stress", be free of porosity; Table IV indicates a level "O" would be the appropriate illustrative sample. As there are no clear definitions for measurable levels of cluster porosity in the codes referred to in this guide, the relationship of the samples of cluster porosity were not directly related to the codes.

Depicting relative levels of roughness and irregular contour is made difficult by the imprecise language to describe the condition in existing codes: For example: "... however, the surface of the welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges or valleys..." and "..., the contour of welds, ... shall blend smoothly and gradually into the base metal." (See Tables V and VI). A SP-7 Panel consensus as to quantitative criteria to more precisely delineate the conditions of irregular contour or roughness could

not be reached; thus the preparation of the samples in terms of condition severity appropriate to each level of application was left to the judgement of each shipyard and the general description given in the Approach.

It should be understood that the conditions illustrated represent levels of severity that may or may not be acceptable depending on the pertinent code or application, as well as their overall frequence of occurrence. There are instances where a shipyard or designer may specify requirements in excess of an allowable code to take into account special requirements: i.e. the presence of porosity may be unacceptable if certain coatings were required to be applied to welded structure or for watertight applications. The conditions illustrated are neither intended as quality targets in the training of welders nor to represent the general level of quality desired in production, in that the condition should ideally be absent, but as a practical matter may be tolerated in isolated instances within prescribed limits.

NAVSSEA 0900-LP-003-8000 applies to structural applications in non-combatant surface ships. ASME applies to marine boilers and pressure vessels, and AWS D1.1 is frequently used for offshore structures. The samples selected illustrate the conditions of undercut and porosity addressed in these codes and others.

In connection with commercial ships, it may be reasonable to relate the classes of illustrated surface conditions in samples to the structural application categories as defined in the ABS Rules for Building and Classing Steel Vessels and Rules for Building and Classing Mobile Offshore Drilling Units. For example: level O (absence of conditions) or level A of a given surface condition might be related to important welds in areas of a ship or offshore structure where special application materials are required by the ABS Rules, levels A or B for other important materials, levels B or C for secondary structures and level C for nonstructural applications.

It should be realized that the developed samples represent a first step in producing a more complete set of samples illustrating commonly encountered weld surface conditions.

## 7. CONCLUSIONS

1. Five sets of samples of butt and fillet welds have been produced; each set illustrates three levels of severity of surface condition for undercut, scattered porosity, cluster porosity, roughness and irregular contour and one butt and fillet weld illustrate re-entrant angles near 90 degrees.

2. Selected conditions of undercut and scattered porosity can be related to existing descriptive standards for visual inspection presently used in the marine industry. Cluster porosity is not specifically addressed by any of the codes studied. The levels of irregular contour and roughness are imprecisely addressed in existing codes. The relationship of the samples of cluster porosity, irregular contour and roughness were not directly related to codes. The condition severity appropriate to each level application was left to the judgement of each fabricator. However, the severity levels selected for these conditions could be a basis for incorporation into existing codes or future guidelines.

3. The use of such samples as visual reference standards to reflect quantitative limitations of surface conditions indicated in a code or shipyard specification could reduce costs in the marine industry by reducing the amount of physical measurements on weld surfaces.

## 8. RECOMMENDATIONS

It is recommended that the proposed basis for visual illustrations of weld surface conditions, i.e., descriptions of weld surface conditions accompanied by three-dimensional replicas of these conditions be presented to pertinent code writing bodies for their consideration for use in connection with published codes.

## APPENDIX

## USER'S GUIDANCE MANUAL

### 1. SCOPE

These reference standards consist of five types of weld surface conditions at three levels of severity in butt and fillet welds. One butt and one fillet welds illustrate the re-entrant angle measurement. These visual reference standards are utilized as a means for establishing the surface condition types and severity level in welds. They may be used as reference standards for a specific contract agreed upon between purchaser and fabricator.

### 2. PLASTIC WELD REPLICAS REPRESENTATION

The weld surface condition severity levels for undercut, scattered porosity and cluster porosity are defined as indicated in Table 1. The selection of representative samples illustrating roughness and irregular contour was based on the consensus of the members of SNAME SP-7 Welding Panel. Sample codes to describe weld replicas representation are shown in Table II. A list of plastic weld replicas representing various surface conditions - undercut, scattered porosity, cluster porosity, irregular contour and roughness at three different severity levels for each surface condition as well as re-entrant angle is shown in Table III. The welding process and position, if known, are also indicated for reference. The samples were selected mainly based on the surface condition regardless of welding process and position. The sample code for each one is shown on the edge of the sample. The relationship between the specific conditions represented by the samples and the specific requirements in the codes is shown in Table IV for undercut and scattered porosity. Depicting relative levels of irregular contour and roughness is made difficult by imprecise language to describe the condition in existing codes. The acceptance standards from various codes are summarized in Table V for irregular contour and Table VI for roughness. A summary of acceptance standards for re-entrant angle in existing codes is listed in Table VII.

## 3. REQUIREMENTS FOR SAMPLE SELECTION

For purpose of evaluations of weld surface conditions a determination must first be made of the structure application to be assigned to the individual structure, namely - critical application structure (critical), general, application structure (intermediate) or secondary application structure (least critical). The surface condition severity level for three application categories is suggested as follows:

| Structure Classification | Applicable Severity Level |
|---|---|
| Critical Application (critical) | O or A |
| General Application (intermediate) | A or B |
| Secondary Application (least critical) | B or C |

## 4. PROCEDURE FOR EVALUATION

4.1 The same length as the reference sample shall be the unit length by which the production weld is evaluated and any such length or any length that shares surface conditions with an adjacent lengh shall meet the surface condition requirement as defined or shown in the sample for acceptability. When the length of interest within a production weld is less than the unit length, such length of interest shall be prorated to the reference sample's length.

4.2 Compare the production welds of the structure for evaluation with the reference samples applicable for the pertinent structure application.

4.3 When the severity level of the surface condition in the production weld being inspected appears equal to or better than the applicable reference sample, the weld is considered satisfactory or acceptable. If the production weld indicates that the severity level is greater than the applicable reference sample the production weld is considered unsatisfactory or rejectable.

4.4 When two or more types of surface conditions are shown in the same production weld, the predominating surface condition type, if rejectable, shall govern regardless of the other types of surface conditions.

4.5 When two or more types of surface conditions are shown in the same production weld and they are both equal to the maximum acceptable severity level of the applicable reference samples for both these surface conditions, the weld shall be considered unacceptable.

## TABLE I

## WELD SURFACE CONDITIONS - SEVERITY LEVELS SELECTED

## - BUTTS AND FILLETS -

**UNDERCUT**

| | |
|---|---|
| Level O: | None present |
| Level A: | 1/64 in. deep continuous |
| Level B: | 1/32 in. deep continuous |
| Level C: | 1/16 in. deep continuous |

**SCATTERED POROSITY**

| | |
|---|---|
| Level O: | None present |
| Level A: | 4 pores 1/32 in. maximum diameter |
| Level B: | 4 pores 1/16 in. maximum diameter |
| or | 7 pores 3/64 in. maximum diameter |
| Level C: | 4 pores 1/8 in. maximum diameter |
| or | equivalent area |

**CLUSTER POROSITY**

| | |
|---|---|
| Level O: | None present |
| Level A: | Multiple pores 1/32 in. maximum diameter within 1/4 in. |
| Level B: | Multiple pores within 1/2 in. |
| Level C: | Multiple pores within 1 in. |

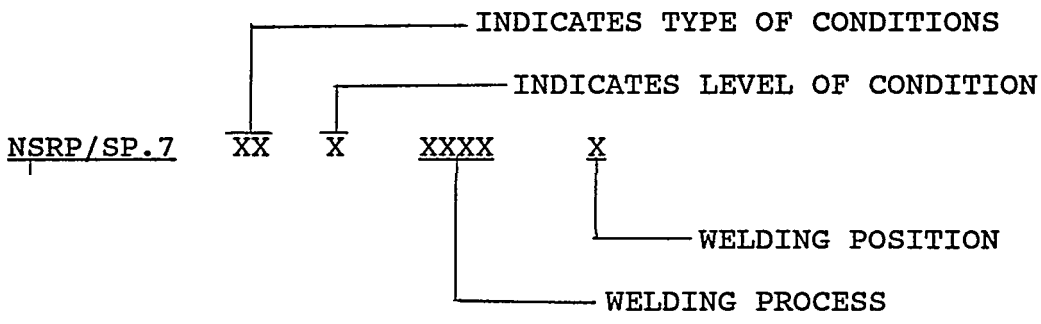
**NOTES:**

1. All of the above definitions are per 6 in. of weld.

2. Level O is to be used for each condition to represent a weld which is free of the surface condition under consideration.

TABLE II

SAMPLE CODES FOR PLASTIC WELD REPLICAS




NATIONAL SHIPBUILDING RESEARCH PROGRAM/SP-7 WELDING PANEL

CONDITION TYPE CODES:

| | | |
|---|---|---|
| Ps | = | POROSITY (SCATTERED) |
| Pc | = | POROSITY (CLUSTER) |
| Uc | = | UNDERCUT |
| RO | = | ROUGHNESS |
| RA | = | RE-ENTRANT ANGLE |
| cx | = | IRREGULAR CONTOUR |

CONDITION LEVEL CODES:

| | | |
|---|---|---|
| A | = | LEAST SEVERE LEVEL OF CONDITION ILLUSTRATED |
| B | = | INTERMEDIATE LEVEL OF CONDITION ILLUSTRATED |
| c | = | MOST SEVERE LEVEL OF CONDITION ILLUSTRATED |

PROCESS CODES:

| | | |
|---|---|---|
| SMAW | = | SHIELDED METAL ARC WELDING |
| SAW | = | SUBMERGED ARC WELDING |
| GMAW | = | GAS METAL ARC WELDING |
| FCAW | = | FLUX CORED ARC WELDING |
| UNK | = | UNKNOWN |

POSITION CODES:

| | | |
|---|---|---|
| F | = | FLAT |
| v | = | VERTICAL |
| o | = | OVERHEAD |
| H | = | HORIZONTAL |
| x | = | UNKNOWN |

# TABLE III

## LIST OF PLASTIC WELD REPLICAS REPRESENTATION

| Project Sponsor | BUTTS* Condition Type | Condition Level | Process | Position | FILLETS* Condition Type | Condition Level | Process | Position |
|---|---|---|---|---|---|---|---|---|
| NSRP/SP.7 | Uc | A | SMAW | F | Uc | A | GMAW | O |
| NSRP/SP.7 | Uc | B | GMAW | v | Uc | B | SMAW | O |
| NSRP/SP.7 | Uc | c | SMAW | F | Uc | c | SMAW | v |
| NSRP/SP.7 | Ps | A | SMAW | F | Ps | A | GMAW | F |
| NSRP/SP.7 | Ps | B | SMAW | o | Ps | B | SMAW | F |
| NSRP/SP.7 | Ps | c | SAW | F | Ps | c | SMAW | H |
| NSRP/SP.7 | Pc | A | SMAW | H | Pc | A | SAW | H |
| NSRP/SP.7 | Pc | B | GMAW | v | Pc | B | GMAW | o |
| NSQP/SP.7 | Pc | c | SMAW | H | Pc | c | GMAW | v |
| NSRP/SP.7 | Cx | A | SMAW | F | cx | A | FCAW | v |
| NSRP/SP.7 | Cx | B | UNK | x | Cx | B | UNK | x |
| NSRP/SP .7 | Cx | c | UNK | x | Cx | c | UNK | x |
| NSRP/SP.7 | RO | A | SMAW | F | RO | A | UNK | x |
| NSRP/SP.7 | RO | B | UNK | x | RO | B | UNK | x |
| NSRP/SP.7 | RO | c | FCAW | v | RO | c | UNK | x |
| NSRP/SP.7 | RA | | | | RA | | | |

* See TABLE II for sample codes

## TABLE IV

## RELATIONSHIP BETWEEN EXISTING ACCEPTANCE STANDARDS & SELECTED SAMPLES
## -UNDERCUT-

| EXISTING STANDARD | APPLICABLE SAMPLES |
|---|---|
| AWS D.1.1-90, Sections 10.17.1.5 and 9.25.1.5 Requirements | |
| Undercut shall be no more than 0.01 in. (0.25mm) deep when its direction is transverse to primary tensile stress in the part that is undercut, | Level A (1/64 in. undercut) (considered meeting 0.01 inch requirement for butts & fillets from AWS) |
| No more than 1/32 in. (1mm) for all other situations | Level B (1/32 in. undercut) for butts and fillets |
| AWS D1.1-90, Section 8.15.1.(5) requirements | |
| For material less than 1 in. thick undercut shall not exceed 1/32"(1mm) | Level B (1/32 in. undercut) for butts and fillets |
| For material thickness less than 1 in. (25.4mm) a max. 1/16 in. (1.6mm) is permitted for an accumulated strength of 2 in. (50mm) in any 12 in. (305 mm). | Level C (1/16 in. undercut) for butts and fillets |
| For material equal or greater than 1 in., Undercut shall not exceed 1/16 in. (1.6mm) for any length of weld. | |
| ASME 1989 Section VIII Div. 1 Para. UW-35 Requirements | |
| The reduction in thickness shall not exceed 1/32 in. (0.8mm) or 10% of the nominal thickness of the adjoining surface, whichever is less | Level A (1/64 in. undercut) for butts & fillets (5/32 in.≤ thickness ≤ 5/16 in.)<br>Level B (1/32 in. undercut) for butts and fillets (thickness ≥ 5/16" in.) |

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| EXISTING STANDARD | APPLICABLE SAMPLES |
|---|---|
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| No more than 1/32 in. (1mm) for all other situations | Level B (1/32 in. undercut) for butts and fillets |
| AWS D1.1-90, Section 8.15.1.(5) requirements | |
| For material less than 1 in. thick undercut shall not exceed 1/32"(1mm) | Level B (1/32 in. undercut) for butts and fillets |
| For material thickness less than 1 in. (25.4mm) a max. 1/16 in. (1.6mm) is permitted for an accumulated strength of 2 in. (50mm) in any 12 in. (305 mm). | Level C (1/16 in. undercut) for butts and fillets |
| For material equal or greater than 1 in., Undercut shall not exceed 1/16 in. (1.6mm) for any length of weld. | |
| ASME 1989 Section VIII Div. 1 Para. UW-35 Requirements | |
| The reduction in thickness shall not exceed 1/32 in. (0.8mm) or 10% of the nominal thickness of the adjoining surface, whichever is less | Level A (1/64 in. undercut) for butts & fillets (5/32 in.≤ thickness ≤ 5/16 in.)<br>Level B (1/32 in. undercut) for butts and fillets (thickness ≥ 5/16" in.) |

**TABLE IV CONTINUED**

**-UNDERCUT-**

| EXISTING STANDARD | APPLICABLE SAMPLES |
|---|---|
| ASME B31.1, 1989<br>Para. 136.4.2 (A.2)<br><br>Unacceptable - Undercut on surface which is greater than 1/32 in. | Level B (1/32 in. undercut) for butts and fillets |
| API RA 2A, 1986<br>Para. 6.4.1 undercut should not exceed 0.01 inch.(0.25mm) | Level A (1/64 in. undercut) for butts and fillets |
| NAVSEA 0900-LP-003-8000, 1967<br>Paragraph 5.2.6 Requirements<br><br>Class 1<br><br>The maximum undercut shall be 1/64 inch or 10% of the adjacent base metal thickness, whichever is less. | Level A (1/64 in. undercut) for butts & fillets (thickness ≥ 5/32 - in.) |
| Class 2 and 3<br><br>The maximum undercut shall be 1/32 in. or 10% of the adjacent base metal thickness, whichever is less | Level B (1/32 in. undercut) for butts & fillets (thickness ≥ 5/16 - in.) |
| For base metal thicknesses 1/2 in. and greater, undercut up to 1/16 in. is allowed if the accumulated length of undercut exceeding 1/32 - in. does not exceed 15% of the joint length or 12 inches in 36 inches length of weld, whichever is less. | Level B (1/32 in. undercut) (Note 1)<br>Level C (1/16 in. undercut)(Note 1) for butts & fillets |

**TABLE IV CONTINUED**

**-UNDERCUT-**

| EXISTING STANDARD | APPLICABLE SAMPLES |
|---|---|
| MIL-STD-1689 (SH), 1983<br>Para. 8.3 Requirement | |
| To meet the criteria specified in NAVSEA 0900-LP-008-8000, Class 3 for ship's hull structures | Level B 1/32 in. undercut) (Note 1)<br>Level C (1/16 in. undercut) (Note 1) for butts and fillets |

Note: (1) These weld samples illustrate the magnitude of the defects. The permissible distribution is specified in the specification.

**TABLE IV CONTINUED**

**- SCATTERED POROSITY -**

| EXISTING STANDARD | APPLICABLE SAMPLES |
|---|---|
| AWS D1.1-90<br><br>Sections 10.17.1.6 and .7 and 8.15.1 (6) and (8) Requirements | |
| <u>Fillet Welds</u> | |
| The sum of diameters of piping porosity (Note 3) in fillet welds shall not exceed 3/8 in. (10mm) in any linear inch of weld and shall not exceed 3/4 in. (19.0mm) in any 12 in. (305mm) length of weld. | <u>Level B</u><br>(4 pores 1/16in.)<br>(Note 1) for fillets<br><br><u>Level C</u><br>(4 pores 1/8 in.)<br>(Note 1) for fillets |
| <u>Butt Welds</u> | |
| Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds piping porosity shall not exceed 3/8 in. (9.5mm) in any linear inch of weld and shall not exceed 3/4 in. (19mm) in any 12 in. (305mm) length of weld. | <u>Level O</u> (Note 2)<br><br><u>Level B</u><br>(4 pores 1/16in.)<br>Note 1) for butts |

**TABLE IV CONTINUED**

**- SCATTERED POROSITY -**

| EXISTING STANDARD | APPLICABLE SAMPLES |
|---|---|
| AWS D1.1-90 Section 9.25.1.6 and .8 Requirements | |
| Fillet Welds | |
| The frequency of piping porosity in fillet welds shall not exceed one in each 4 in. (100 mm) of weld length and the maximum diameter shall not exceed 3/32 in. (2 mm). Exception for fillet welds connecting stiffness to web, the sum of the diameters of piping porosity shall not exceed 3/8 in. (10 mm) in any linear inch of weld and shall not exceed 3/4 in. (19mm) in any 12 in. (305 mm) length of weld. | Level B<br>(4 pores 1/16 in.)<br>(Note 1) for fillets<br><br>Level C<br>(4 pores 1/8 in.)<br>(Note 1) for fillets |
| Butt Weld | |
| Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the frequency of piping porosity shall not exceed one in 4 in. (100 mm) of length and the maximum diameter shall not exceed 3/32 in. (2 mm). | Level O (Note 2)<br><br>Level B<br>(4 pores 1/16 in.)<br>(Note 1) for butts<br><br>Level C<br>(4 pores 1/8 in.)<br>(Note 1) for butts |
| AME Section VIII Division 1, 1989 Appendix 8 Para. 8.3, 8.4 Requirements | |
| All surfaces to be examined shall be free of: | |
| Four or more rounded defects in line separated by 1/16 in. (1.6mm) or less (edge to edge). | Level A<br>(4 pores 1/32 in.)<br>(Note 1) for butts & fillets |

**TABLE IV CONTINUED**

**- SCATTERED POROSITY -**

| EXISTING STANDARD | APPLICABLE SAMPLES |
|---|---|
| NAVSEA 0900-LP-003-8000 Paragraph 5.3.2.2 requirements | |
| Linearly aligned rounded indications as defined in 2.19 (four or more indications in a line any one of which is separated from the adjacent indicating by less than 1/16" or D whichever is greater, where D is the major diameter of the larger of the adjacent indications), shall be cause for rejection if one or more of the indications is 1/32-inch diameter or greater for Class 1 | Level A (4 pores 1/32 in.) (Note 1) for butts and fillets |
| 1/16 inch or greater for Class 2 | Level B (4 pores 1/16in.) Note 1) for butts and fillets |
| 3/16 inch or greater for Class 3 | Level C (4 pores 1/8 in.) (Note 1) for butts and fillets |

Notes: (1) These weld samples illustrate the magnitude of the defect. The permissible distribution is specified the specification.

(2) Presence of this defect is not permissible. One perfect sample would apply to all cases when the presence of any type of defect is not allowed.

(3) 1/32 in. (1mm) or greater is added between piping porosity and in fillet welds in Para 8.15.1 (6) and (8).

## TABLE V

## SUMMARY OF ACCEPTANCE STANDARDS (IRREGULAR CONTOUR)

| | |
|---|---|
| MIL-STD-1689 (SH)<br>Para. 14.3.1 | Welds should be free of sharp irregularities between beads |
| NAVSEA<br>0900-LP-003-8000<br>Surface Inspection | not addressed |
| AWS D1.1-90<br>Structural Welding Code | not addressed |
| ABS, 1990<br>Section 30A.5.8.a<br>Steel Vessel Rules | The surfaces of welds... are to be regular and uniform. |
| ASME<br>Section VIII Div. 1<br>Pressure Vessels | not addressed |
| ASME, 1989<br>Section I<br>Power Boilers | not addressed |
| API RP 2A, 1986<br>Fixed Offshore Platforms | not addressed |

## TABLE VI

## SUMMARY OF ACCEPTANCE STANDARDS

## (ROUGHNESS)

| | |
|---|---|
| MIL-STD-1689 (sh)<br>Para. 14.3.1<br>Fabrication, Welding<br>and Inspection | Welds shall be free of sharp irregularities between beads |
| NAVSEA<br>09--LP-003-8000<br>Surface Inspection | not addressed |
| AWS D1.1-90<br>Structural Welding Code | not addressed |
| ABS, 1991<br>Section 30A.5.8.a<br>Steel Vessel Rules | The surfaces of the welds... are to be regular and uniform. |
| ASME 1989<br>Section VIII Div. 1<br>Pressure Vessels | As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples,grooves, overlaps abrupt ridges and valleys. |
| ASME, 1989<br>Section I PW35<br>Para. 35.1<br>Power Boilers | As-welded surfaces are permitted; however, the surface of the welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to avoid stress raisers. |
| API RP2A, 1986<br>Fixed Offshore Platforms | not addressed |

**TABLE VII**

SUMMARY OF ACCEPTANCE STANDARDS

(RE-ENTRANT ANGLE)

| | |
|---|---|
| MIL-STD-1689 (SH)<br>Para. 8.3.1<br><br>Fabrication, Welding and Inspection | Except as required for NDT, the as-deposited surfaces at the weld edge shall be acceptable provided they do not form a re-entrant angle less than 90 degrees with the base plate. |
| NAVSEA<br>0900-LP-003-8000<br>Para.5.2.1.6<br>Surface Inspection | When required..., the contour of welds, with the exception of undercut within specification allowances, shall blend smoothly and gradually into the base metal. |
| AWS D.1.1-90<br>Para. 3.6.2<br>Structural Welding Code | In the case of butt.., the reinforcement .... shall have gradual transition to the plane of the base metal surface. |
| ABS, 1991 30A.5.8a<br>Section 30.5.8a<br>Steel Vessels Rules | The surface of the welds are to be..... reasonably free from.... overlap. |
| ASME, 1989<br>Section I<br>Power Boilers | not addressed |
| Section VIII Div. 1<br>Pressure Vessels | not addressed |
| API RP 2A, 1986<br>Para. 6.4.1<br>Fixed Offshore Platforms | Weld profiles... should merge smoothly with the base metal of both brace and chord. |

A word about the NSRP

The National Shipbuilding Research Program (NSRP) has been engaged in research related to improvements in shipbuilding in the U.S. since 1973. The program is a cooperative effort involving commercial and U.S. Naval shipyards and related agencies, industries and educational institutions.

Since the inception of the NSRP, R&D projects have made significant contributions to shipbuilding in the areas of facilities, environmental considerations, outfitting, productions aids, design and production integration, welding, industrial engineering, education and training, automation and coatings. A bibliography and library of NSRP project reports and related documents, training films and videos is maintained at the University of Michigan, Transportation Research Institute, Ann Arbor, Michigan.

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